Application Brief

mmWave Radar Sensing and Sensor Fusion in Humanoid Robots

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Humanoid robots are gaining significant attention across industries due to the potential to automate tasks, perform human-like movements, and engage in social interaction. Applications for these robots range from healthcare, where humanoids assist patients, to industrial automation, education, and research. The development of humanoid robotics presents several challenges, including replicating complex human movements, achieving autonomous decision-making, and creating systems with the capability to adapt to unstructured environments.

Figure 1. Modern Humanoid Robot

Importance of Sensing in Humanoids

A critical aspects of humanoid robots is the ability to detect and decipher a physical environment; as humans rely on senses to navigate and interact with the world, humanoid robots also require sophisticated sensing systems to perform tasks autonomously and effectively. Common types of sensors used in humanoid robots include visual systems (cameras), radars and LiDARs (navigation and perception), tactile sensors (mimicking touch), and auditory systems (microphones) which allow the robot to understand its own posture and balance. This application brief explores the benefits of millimeter wave (mmWave) radar sensors for navigation, identification, and integrating radar with camera sensors to enable sensor fusion in humanoid robots.

Introduction to mmWave Radar Sensors

Long-range capabilities, high-motion sensitivity, and privacy features make radar-based sensor integrated circuits (IC) a popular technology for position and proximity sensing designs. Performing with high accuracy, radar sensors are also popular in automotive and industrial markets for detecting blind-spots, collisions, people, and motion.

60-GHz and 77-GHz radar sensors are replacing 24-GHz radar sensors, delivering higher resolution, improved accuracy, and a smaller form factor. The 60-GHz and 77-GHz radar bands enable new applications, such as object presence detection in industrial robotics and mobile robotics applications found in factories or homes.

Figure 2. mmWave Sensor Embedded in Industrial Robots

Benefits of mmWave Sensors Over LiDAR and Cameras

mmWave Radar technology is often chosen over LiDAR, cameras, and other optical sensors for cost savings due to the ability of radar to work well in adverse weather conditions; cameras can be affected by poor lighting and weather. Radar also has broad range and coverage, allowing sensors to detect objects from over one hundred meters. With mobile robotic applications needing to save on power consumption, frequently users use radar that reaches as low as 1.7mW for presence detection. However, a combination of radar and LiDAR, a camera, or an alternative optical sensor type is usable in a wide variety of use-case scenarios.

From a functional safety standpoint, TI engineers design non-contact radar sensors, such as the IWR6843, following an extensive hardware and software development process, and with device certification from (TÜV) SÜD. All TI radar sensors include built-in functional safety mechanisms that provide the necessary diagnostic coverage required by IEC 61508 to meet hardware capabilities, as high as Safety Integrity Level (SIL) 2 at the component level.

Functional safety collateral is available online through a diagnostic software library, compiler qualification kits, third-party operating systems, development tools, and additional documentations allowing engineers to streamline the safety design process and system-level certification.

Sensor Fusion

Using one type of sensor in humanoid robots presents significant limitations, including incomplete or inaccurate data collection. For example, cameras can struggle with depth perception, poor lighting, or detecting non-visual elements, and LiDAR sensors can collect inaccurate readings because a laser light bounces up and down when the robot is moving. Data collection constraints can lead to errors in navigation, object manipulation and environmental interaction.

Sensor fusion addresses these issues by integrating data from multiple sensors to create a more accurate, reliable, and comprehensive understanding of the robots environment. By combining inputs from various sensing modalities, humanoid robots can make more informed decisions, enhancing the ability to perform complex tasks such as navigating uneven terrain, grasping objects of different shapes and sizes, and interacting in dynamic, real-world environments. Advantages of sensor fusion include:

1. *Increased accuracy* by merging data from different sensors.
2. *Redundancy* to confirm functionality if one sensor fails.
3. *Improved environmental awareness* with a fuller view of surroundings.
4. *Better adaptability* to dynamic environments.

Radar and Camera Sensor Fusion

Radar is one of the top sensors frequently integrated into a system due to the durability of radar in harsh conditions, as well as reliability when detecting moving objects. To mitigate short comings of single sensor systems, TI has various offerings for users interested in maximizing robotic accuracy and awareness. TI offers a camera and radar sensor module with an IMX219 camera and IWR6843ISK EVM mmWave radar sensor. This module implements an object-level fusion approach that applies a camera-vision processing chain and radar processing chain focused on object clustering and tracking, allowing users to track and detect objects in a three-dimensional environment. Users demonstrate the many possibilities and capabilities of sensor fusion in the robotics SDK.

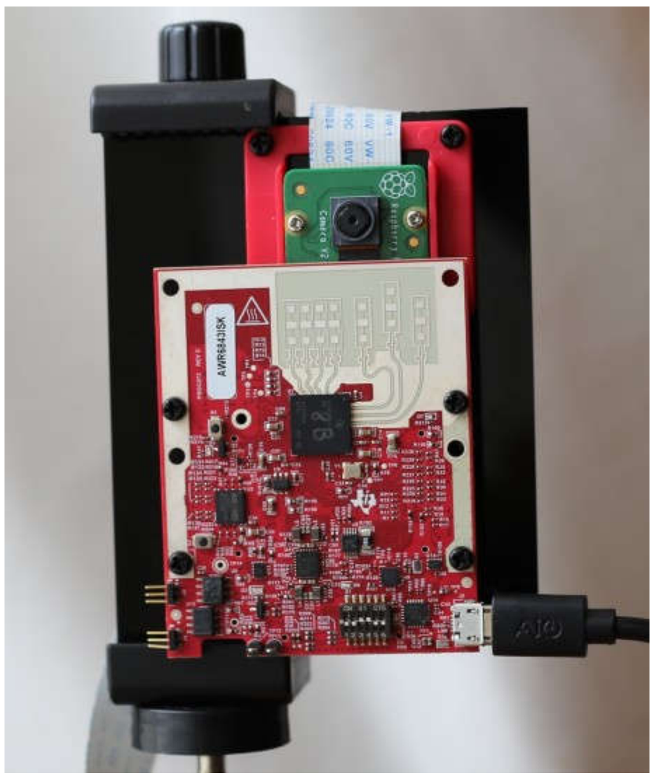

Figure 3. Camera and Radar Sensor Module Built With IMX219 and IWR6843ISK

Summary

This application brief explores the benefits of mmWave sensing, safety, and sensor fusion in enabling precise detection of objects and movements around the humanoid robots. The mmWave sensing technique is particularly valuable in low-visibility conditions, such as dim lighting or dust, where traditional vision-based sensors can be unreliable. mmWave radars are low-cost, consume less-power, and function in adverse weather conditions, making the mmWave Radars a potential choice for robotic applications.

This application brief also addresses functional safety and sensor fusion techniques, which are crucial for the reliable operation of humanoid robots in complex environments. With built-in functional safety mechanisms and a device safety certification from (TÜV) SÜD, TI radar devices provide the necessary diagnostic coverage required by IEC 61508 to meet hardware capabilities as high as SIL 2 at the component level. Combining the safety enabled radars in with LiDAR, cameras or other optical sensors helps to improve accuracy in object detection, failure-redundancy, decision-making, and real-time adjustments in robot behavior to advance both autonomy and safety in humanoid robotic systems.

References

Texas Instruments, Humanoid robot overview

Texas Instruments, Webinar: Sensing in Robotics

Texas Instruments, Radar Toolbox for mmWave Sensors

Texas Instruments, Camera and Radar Fusion Demonstration

Texas Instruments, IWR6843AOP evaluation module for single-chip 60GHz antenna-on-package (AoP) mmWave sensor product page

Texas Instruments, D3 Engineering DesignCore® radar evaluation modules product page

Texas Instruments, Optimizing functional safety for industrial robots white paper

Texas Instruments, Streamlining Functional Safety Certification in Automotive and Industrial functional safety manual

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